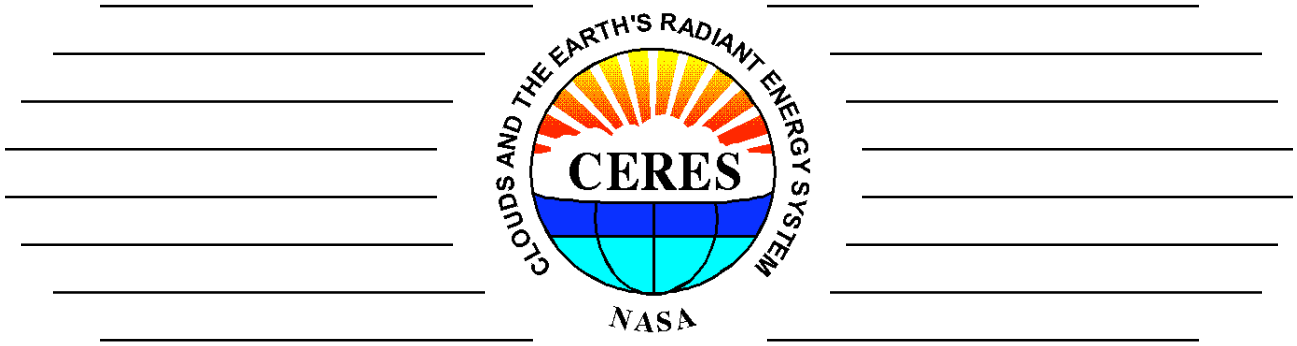
Terra/Aqua Instrument and ERBE-Like Calibration Status Report



Kory J. Priestley
Robert Lee, Susan Thomas, Grant Matthews
Robert Wilson, Pete Spence, Ed Kizer, Peter Szewczyk
Phil Hess, Denise Cooper, Dale Walikainen,

CERES Science Team Meeting
Boulder, CO
March 29-31, 2004

NASA Langley Research Center
Atmospheric SCIENCES

CERES Terra/Aqua Health & Status

To date, the CERES Terra/Aqua instruments are functioning nominally…

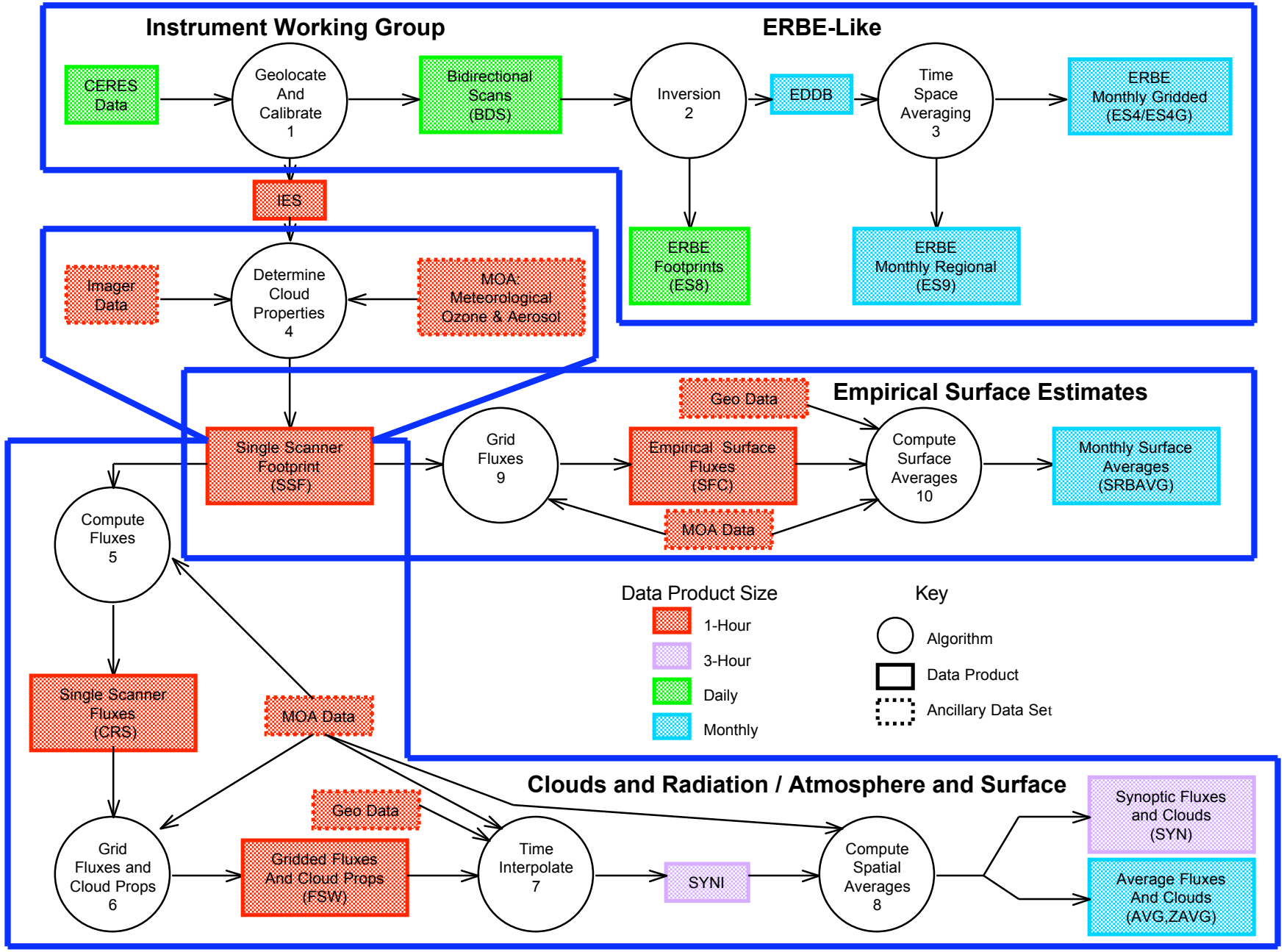
All temperatures and voltages remain within limits

No discernable or alarming trends.

Spacecraft	Instruments	Launch	Science Initiation	Collected Data (Months)
TRMM	PFM	11/97	1/98	9
Terra	FM1, FM2	12/99	3/00	48 +
Aqua	FM3, FM4	5/02	6/02	21 +
?	FM5	?	?	?

Aqua pitchover maneuver tentatively scheduled for Fall 2004.

CERES Top Level Data Flow Diagram



CERES BDS and ERBE-Like Product Status

Spacecraft	Product	Version	Available	Months Processed
TRMM	BDS	Edition1	Yes	1/98 - 8/98
	ERBE-Like	Edition1	Yes	1/98 - 8/98
		Edition2	Yes	1/98 - 8/98
Terra	BDS	Edition1	Yes	2/00 - present
		Edition2	Yes	2/00 - 6/03
	ERBE-like	Edition1	Yes	2/00 - present
		Edition2	Yes	2/00 - 6/03
Aqua	BDS	Edition1	Yes	6/02 - present
		Edition2	Yes	6/02 - 6/03
	ERBE-like	Edition1	Yes	6/02 - present
		Edition2	Yes	6/02 - 6/03

CERES BDS and ERBE-Like Product Status

Spacecraft	Product	Version	Available	Months Processed
TRMM	BDS	Edition1	Yes	1/98 - 8/98 , 3/00
	ERBE-Like	Edition1	Yes	1/98 - 8/98 , 3/00
		Edition2	Yes	1/98 - 8/98 , 3/00
Terra	BDS	Edition1	Yes	2/00 - present
		Edition2	Yes	2/00 - 6/03
	ERBE-like	Edition1	Yes	2/00 - present
		Edition2	Yes	2/00 - 6/03
Aqua	BDS	Edition1	Yes	6/02 - present
		Edition2	Yes	6/02 - 6/03
	ERBE-like	Edition1	Yes	6/02 - present
		Edition2	Yes	6/02 - 6/03

CERES BDS Radiometric Inputs

		Radiometric Gain Values		Radiometric Gain Temporal Variation		WN Channel
Spacecraft	Version	Ground	In-Flight	Static	Varying	SW Correction
TRMM	Ed1	X		X		
	Ed2	-	-	-	-	-
Terra	Ed1	X		X		After 3/04
	Ed2		X		X	After 3/04
Aqua	Ed1		X	X		After 3/04
	Ed2		X		X	X

CERES BDS Radiometric Inputs

		Radiometric Gain Values		Radiometric Gain Temporal Variation		WN Channel
Spacecraft	Version	Ground	In-Flight	Static	Varying	SW Correction
TRMM	Ed1	X		X		
	Ed2	-	-	-	-	-
Terra	Ed1	X		X		After 3/04
	Ed2		X		X	After 3/04
Aqua	Ed1		X	X		After 3/04
	Ed2		X		X	X

CERES Science Team strongly urges data users to utilize Edition2 products in their studies.

CERES ERBE-Like Radiometric Inputs

		Spectral Response Values		Spectral Response Temporal Variation	
Spacecraft	Version	Ground	In-Flight	Static	Varying
TRMM	Ed1	X		X	
	Ed2		X	X	
Terra	Ed1		X	X	
	Ed2		X		X
Aqua	Ed1		X	X	
	Ed2		X		X

CERES ERBE-Like Radiometric Inputs

		Spectral Response Values		Spectral Response Temporal Variation	
Spacecraft	Version	Ground	In-Flight	Static	Varying
TRMM	Ed1	X		X	
	Ed2		X	X	
Terra	Ed1		X	X	
	Ed2		X		X
Aqua	Ed1		X	X	
	Ed2		X		X

CERES Science Team strongly urges data users to utilize Edition2 products in their studies.

INSTRUMENT WORKING GROUP

CLOUDS AND THE EARTH'S RADIANT ENERGY SYSTEM

ACTIVITIES

Choose from one of the links below:

Ground Calibration

Deep Space Calibration

Validation

Field Campaigns:

CLAMS | CRYSTAL-FACE | INDOEX
LaRC-ULDB | GERB | Aerosols
Terra/Aqua Intercalibration
Solar Principal Plane Scans (PPS)

Event Calendar: 2003

NASA LaRC

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Last Updated: Tue Apr 29 13:03:55 2003
Web Curator: Phil Hess (p.c.hess@larc.nasa.gov)
Responsible NASA Official: Kory Priestley (k.j.priestley@larc.nasa.gov)

CERES Home Page

INSTRUMENT WORKING GROUP

CLOUDS AND THE EARTH'S RADIANT ENERGY SYSTEM

Introduction | Activities | Documentation | Operations | Production | Data | Personnel

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Solar Principal Plane Scans (PPS)

Event Calendar: 2003

http://asd-www.larc.nasa.gov/Instrument/

NASA LaRC

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Last Updated: Tue Apr 29 13:03:55 2003
Web Curator: Phil Hess (p.c.hess@larc.nasa.gov)
Responsible NASA Official: Kory Priestley (k.j.priestley@larc.nasa.gov)

CERES Home Page

Edition2 BDS and ERBE-Like Products: Drift Removal Methodology

Drifts are modeled as originating from either of 2 physical entities…..

- **Radiometric Gain Change**
  - **Wavelength independent change in sensor responsivity**
  - **Corrections implemented in Count Conversion algorithm (SS1)**

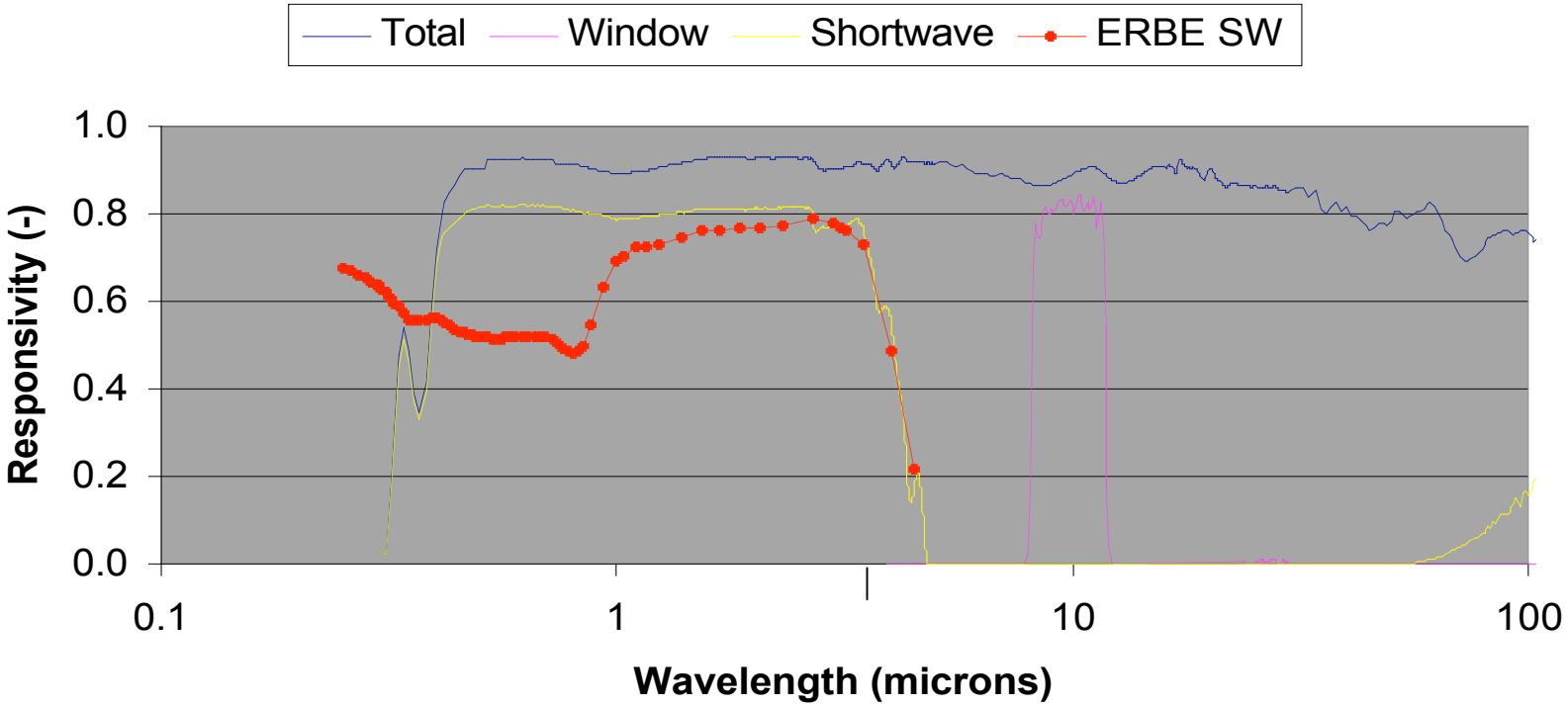
- **Spectral Response Change**
  - **Wavelength dependent change in sensor absorptivity**
  - **Corrections implemented in Spectral Unfiltering algorithms (SS2)**

- **Updated Radiometric Gains and Spectral Response Functions will be generated on a monthly basis and will be implemented on either a daily (Gains) or monthly (Spectral) interpolated basis.**

Instrument has delivered corrections for the first 40 months of Terra data.

CERES Spectral Response Function

TRMM/PFM Edition1 Data Products



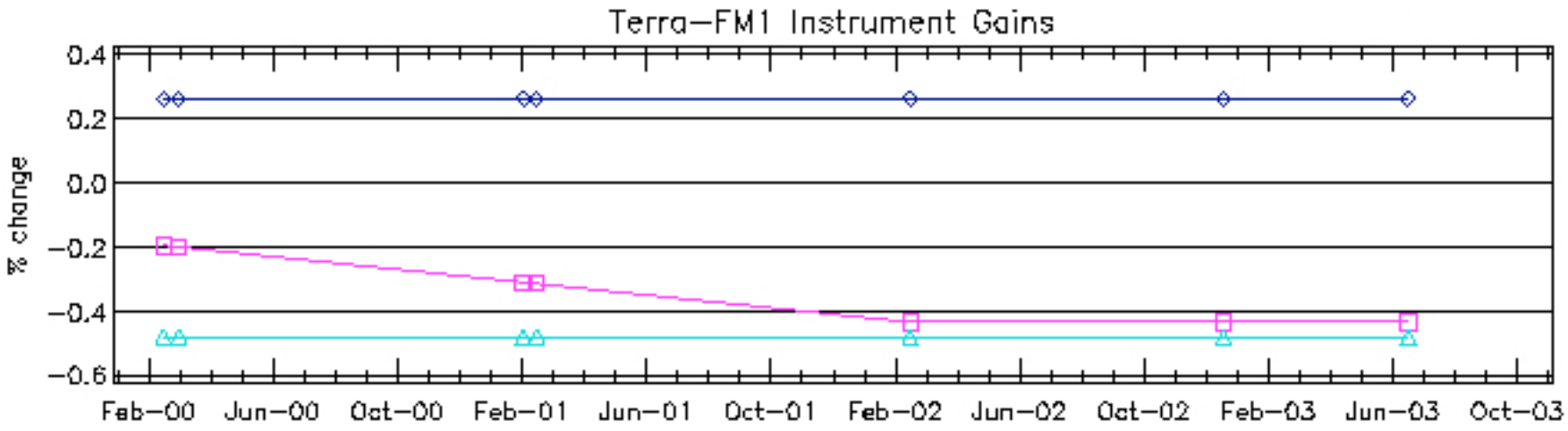
Note: LW_{DAY} = Total - Shortwave

CERES Gain/Spectral Change Summary

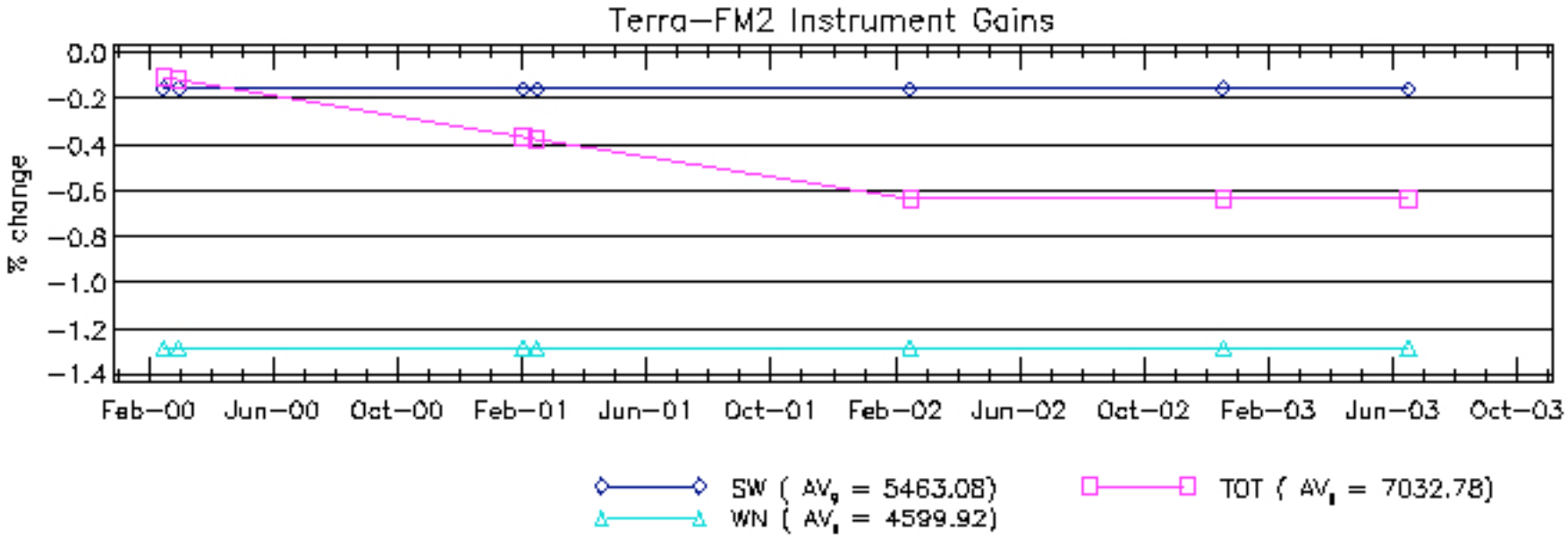
		Channel Gain (%)			Channel Spectral Response (%)				TOA Flux (W/m^2)		
Spacecraft		TOT	WN	SW	SW	WN	SW/ TOT	LW/ TOT	SW	LWDay	LWNight
Terra	FM1	.25	-	-	-	-	.45	-	-	1.1	.65
	FM2	.40	-	-	.40	-	2.6	-	.4	3.6	1.0
Aqua	FM3	.20	-	.30	-	-	1.1	-	.3	1.6	.50
	FM4	.20	-	.50	-	-	1.0	-	.5	1.6	.50

1. All values are maximum on-orbit changes
2. Ground to flight shifts are accounted for separately
3. SW/TOT < 3.0 microns, LW/TOT > 3.0 microns
4. TOA Flux values are all-sky global averages

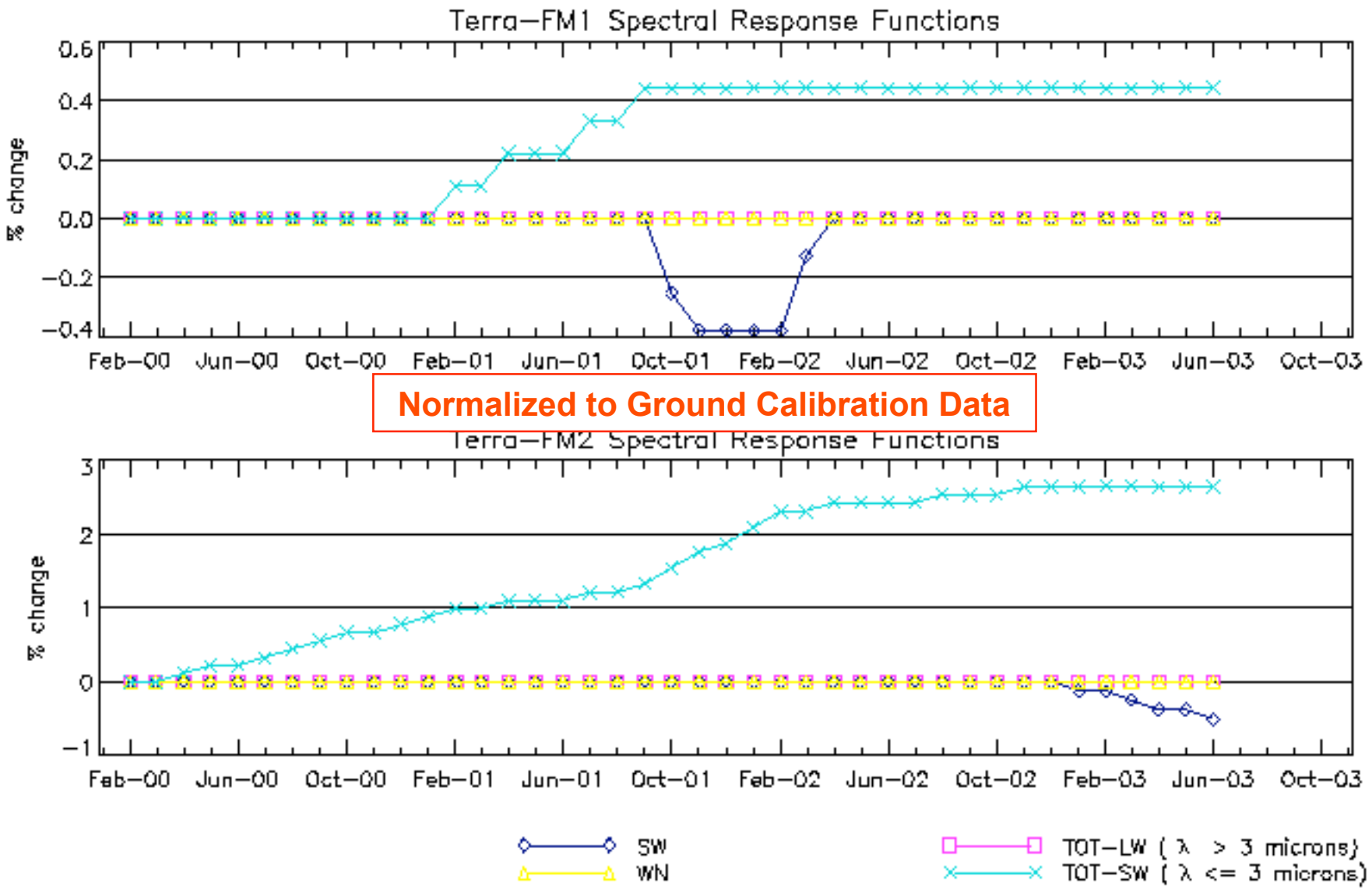
CERES Terra Edition2 Gain Updates



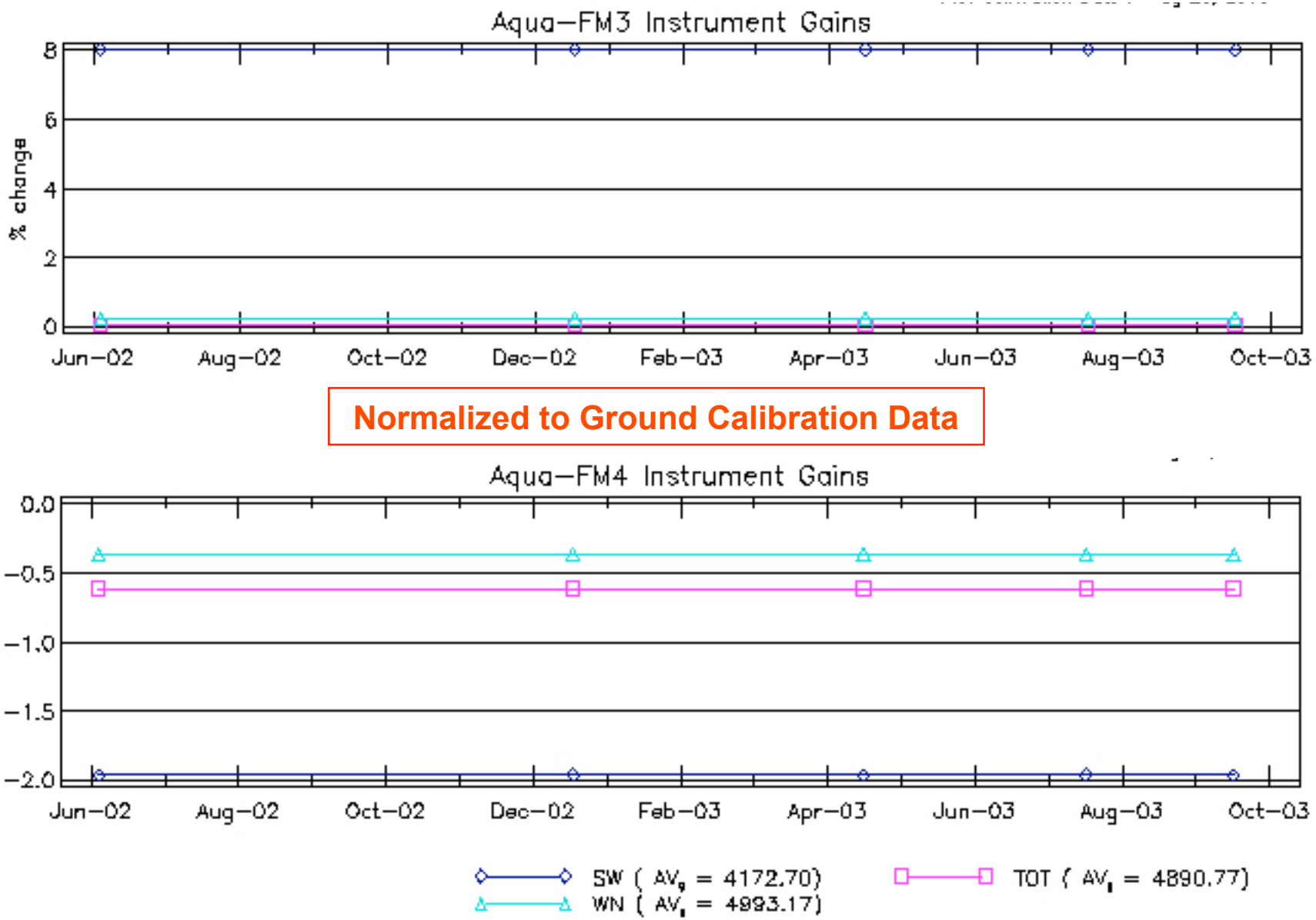
Normalized to Ground Calibration Data



CERES Terra Edition2 Spectral Updates



CERES Aqua Edition1 Gain Updates



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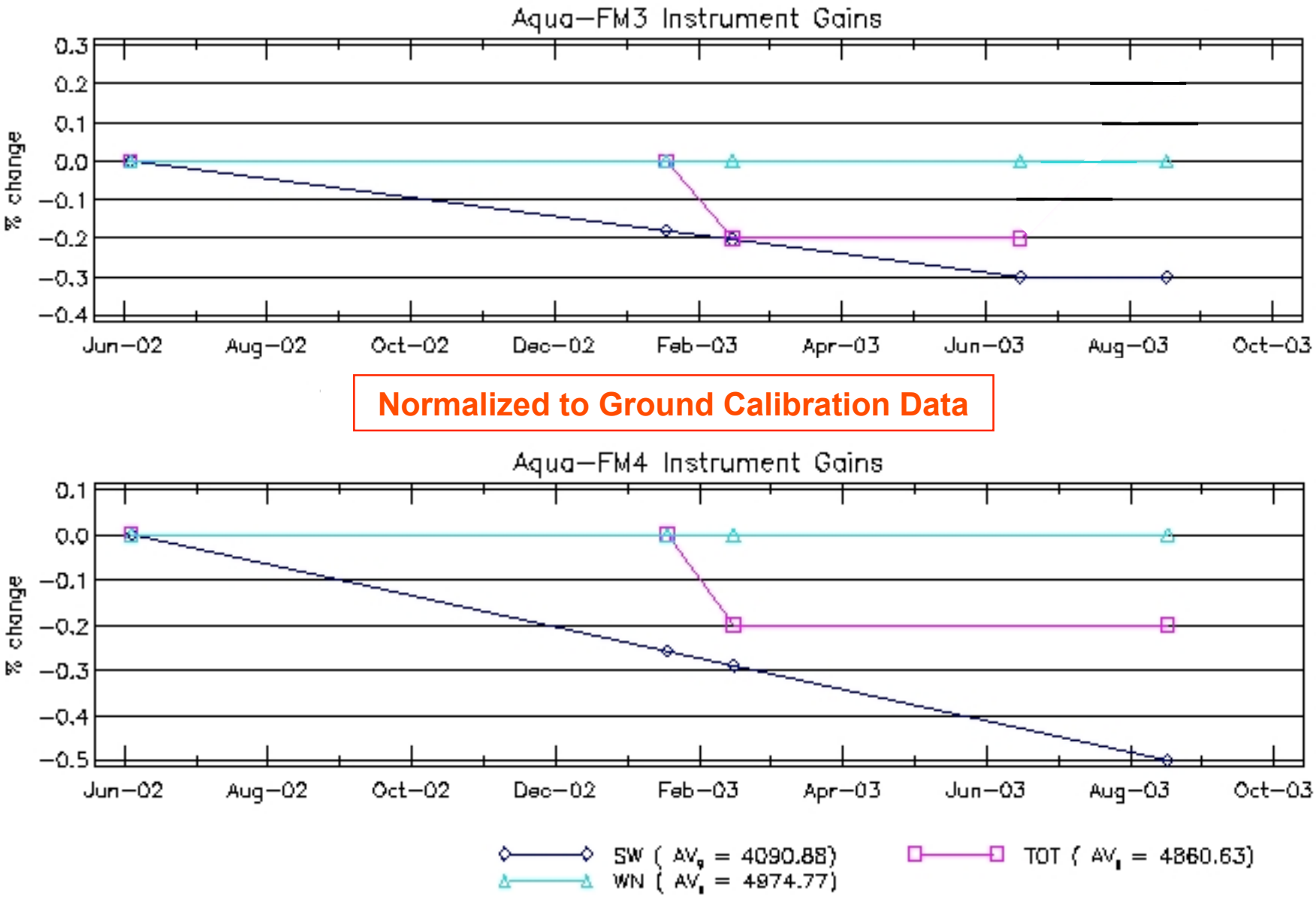
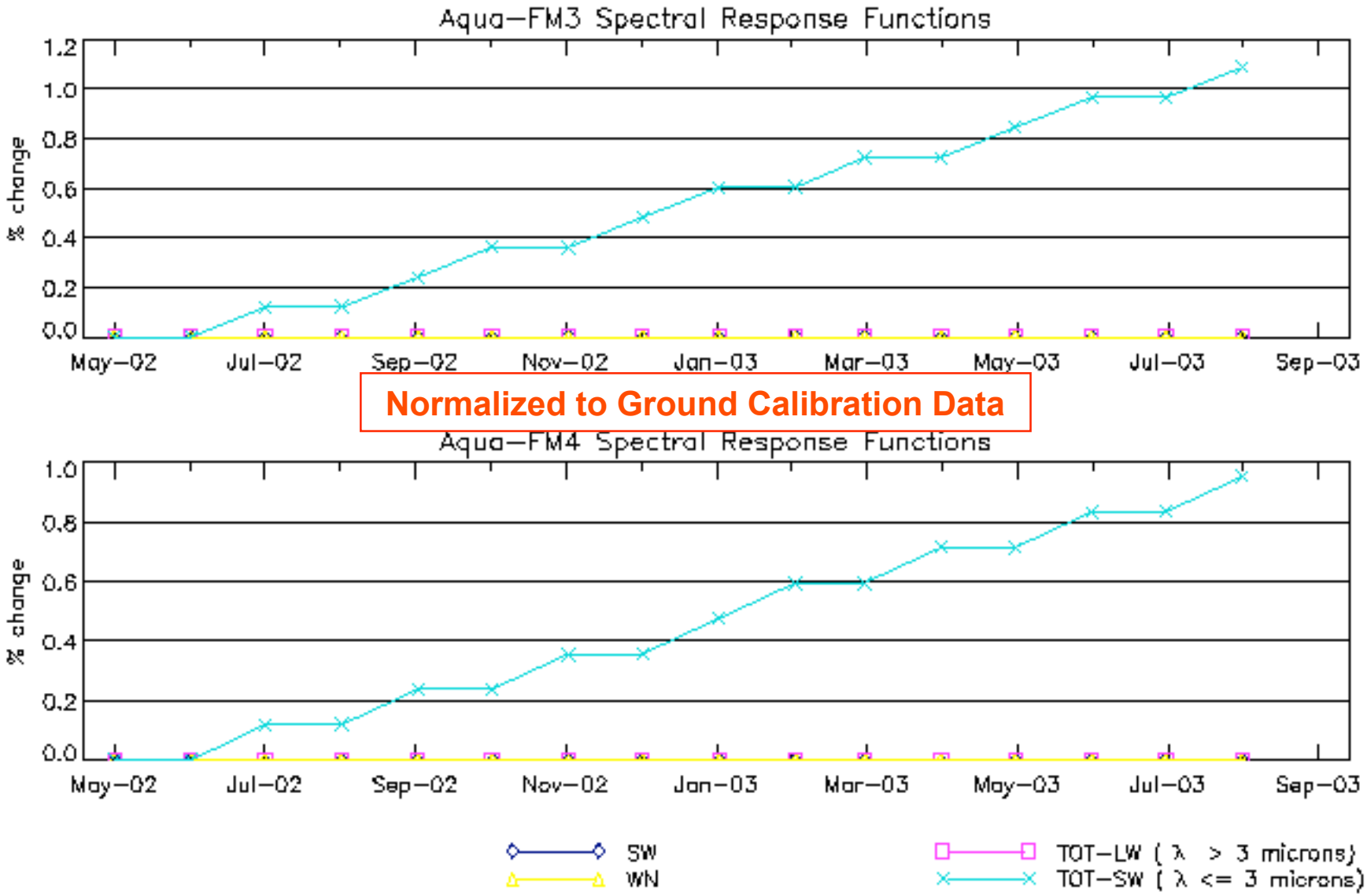
CERES Aqua Edition2 Gain Updates



Normalized to Ground Calibration Data

CERES Aqua Edition2 Spectral Updates



CERES Instrument Radiometric Validation Activities

		Product	Spatial Scale	Temporal Scale	Metric	Spectral Band
On-Board	Internal BB	Filtered Radiance	N/A	N/A	Absolute Stability	TOT, WN
	Internal Lamp	Filtered Radiance	N/A	N/A	Absolute Stability	SW
	Solar	Filtered Radiance	N/A	N/A	Relative Stability	TOT, SW
Vicarious	Theoretical Line-by-Line	Filtered Radiance	> 20 Km	Instantaneous	Inter-Channel Theoretical Agreement	TOT, WN
	Unfiltering Algorithm Theoretical Validation	N/A	N/A	N/A	N/A	TOT, SW, WN
	Inter-satellite (Direct Comparison)	Unfiltered Radiance	1-deg Grid	1 per crossing	Inter-Instrument Agreement, Stability	TOT, SW, WN
	Globally Matched Pixels (Direct Comparison)	Unfiltered Radiance	Pixel to Pixel	Daily	Inter-Instrument Agreement	TOT, SW, WN
	Tropical Mean (Geographical Average)	Unfiltered Radiance	20N – 20S	Monthly	Inter-Channel Agreement, Stability	TOT, WN
	DCC Albedo	Unfiltered Radiance	>40 Km	Monthly	Inter-Instrument agreement, Stability	SW
	DCC 3-channel	Unfiltered Radiance	>100 Km	Monthly	Inter-Channel consistency, stability	TOT, SW
	TIme Space Averaging	Fluxes	Global	Monthly	Inter-Instrument Agreement	LW, SW
	Lunar Radiance Measurements	Filtered Radiance	Sub Pixel	Quarterly	Inter-Instrument Agreement	LW, SW, WN

CERES Instrument Radiometric Validation Activities

		Product	Spatial Scale	Temporal Scale	Metric	Spectral Band
On-Board	Internal BB	Filtered Radiance	N/A	N/A	Absolute Stability	TOT, WN
	Internal Lamp	Filtered Radiance	N/A	N/A	Absolute Stability	SW
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	Unfiltering Algorithm Theoretical Validation	N/A	N/A	N/A	N/A	TOT, SW, WN
	Inter-satellite (Direct Comparison)	Unfiltered Radiance	1-deg Grid	1 per crossing	Inter-Instrument Agreement, Stability	TOT, SW, WN
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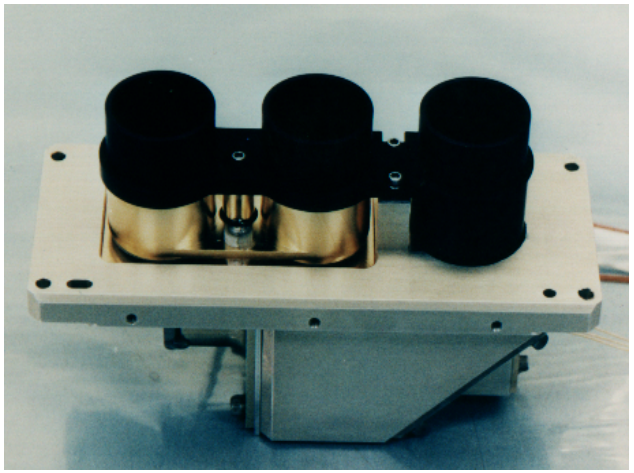
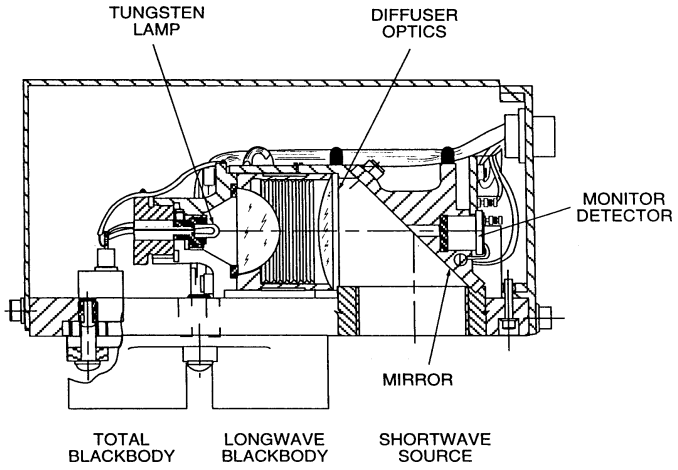
	Lunar Radiance Measurements	Filtered Radiance	Sub Pixel	Quarterly	Inter-Instrument Agreement	LW, SW, WN

CERES Onboard Calibration Sources

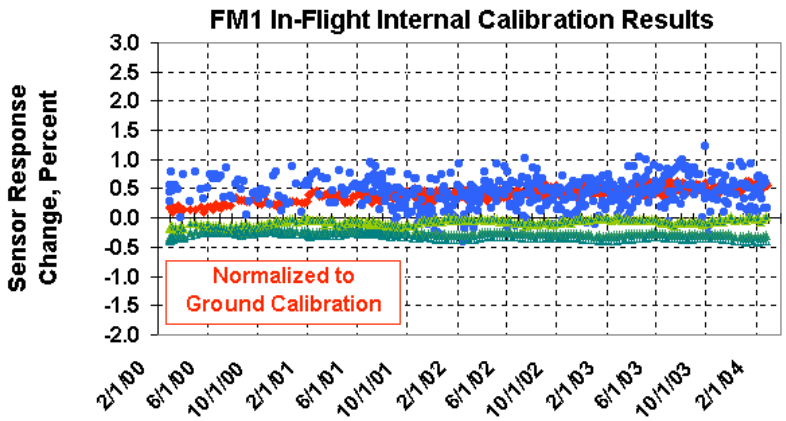
Internal Calibration Module (ICM)

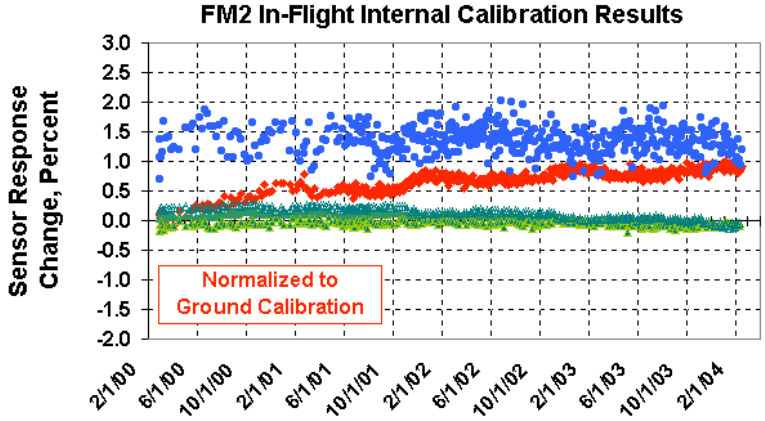
- Blackbodies for the Total and Window channels
- Temperature knowledge obtained via Platinum Resistance Thermometers
- Quartz-halogen tungsten lamp for the Shortwave channel
- ICM Provides 3 unique radiance levels for the SW and LW sources

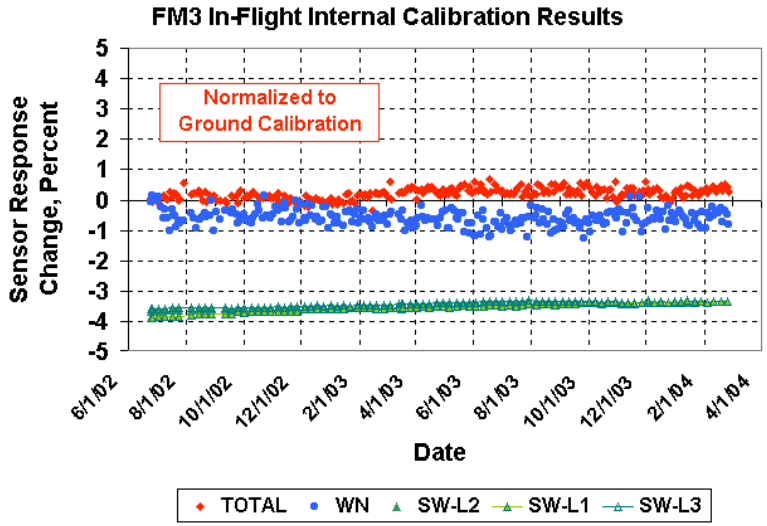


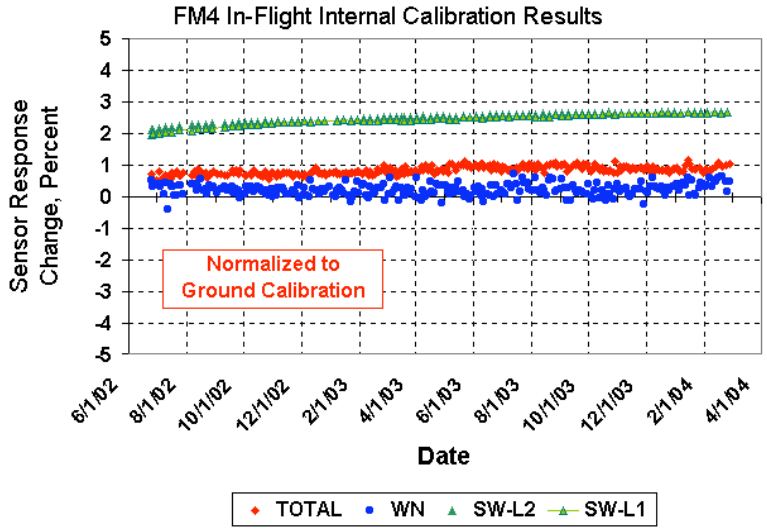


CERES Internal Calibration Results

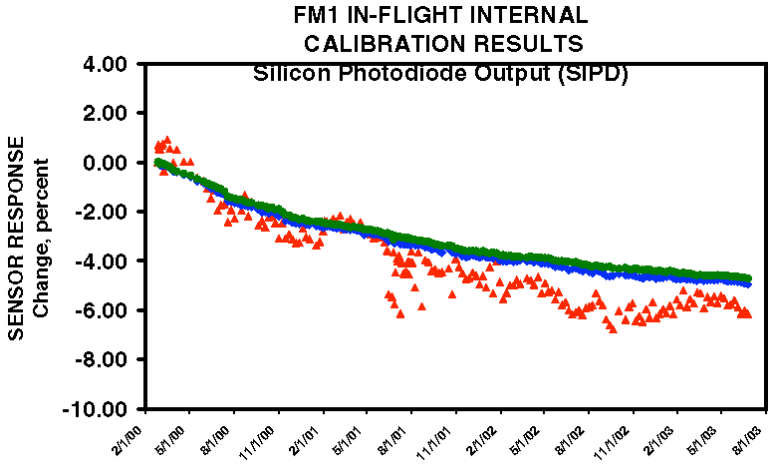


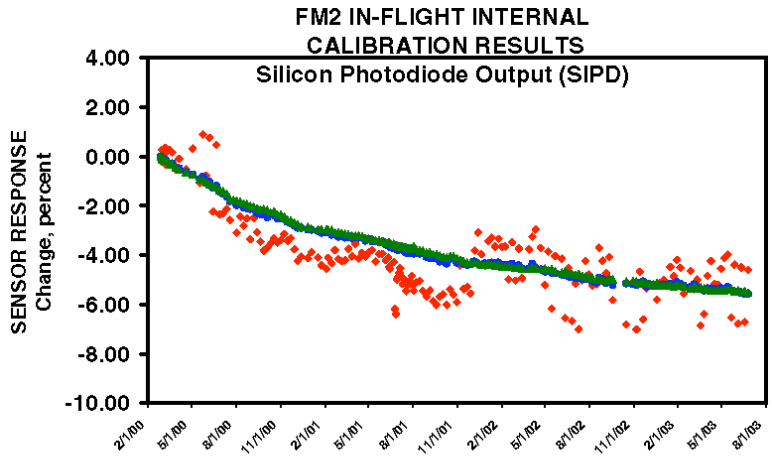


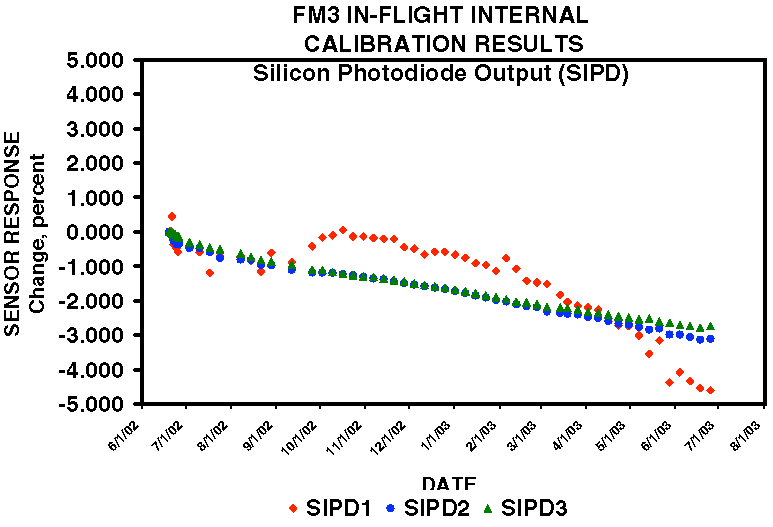


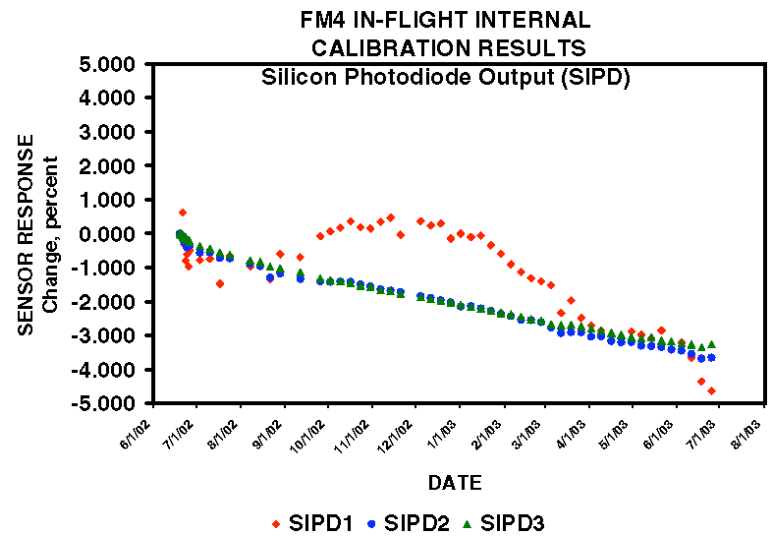


CERES SiPD Results









CERES Instrument Radiometric Validation Activities

		Product	Spatial Scale	Temporal Scale	Metric	Spectral Band
On-Board	Internal BB	Filtered Radiance	N/A	N/A	Absolute Stability	TOT, WN
	Internal Lamp	Filtered Radiance	N/A	N/A	Absolute Stability	SW
	Solar	Filtered Radiance	N/A	N/A	Relative Stability	TOT, SW
Vicarious	Theoretical Line-by-Line	Filtered Radiance	> 20 Km	Instantaneous	Inter-Channel Theoretical Agreement	TOT, WN
	Unfiltering Algorithm Theoretical Validation	N/A	N/A	N/A	N/A	TOT, SW, WN
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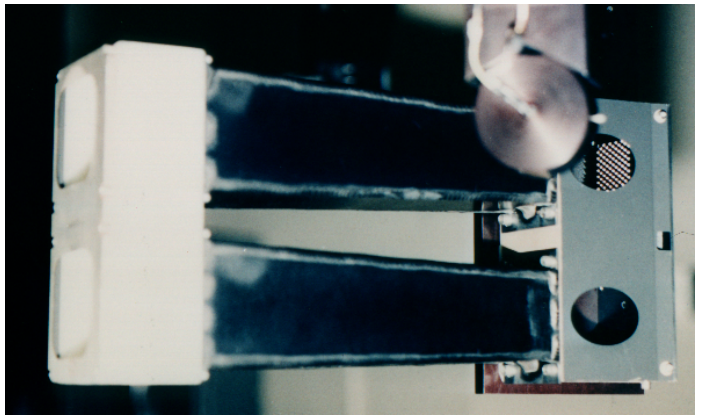
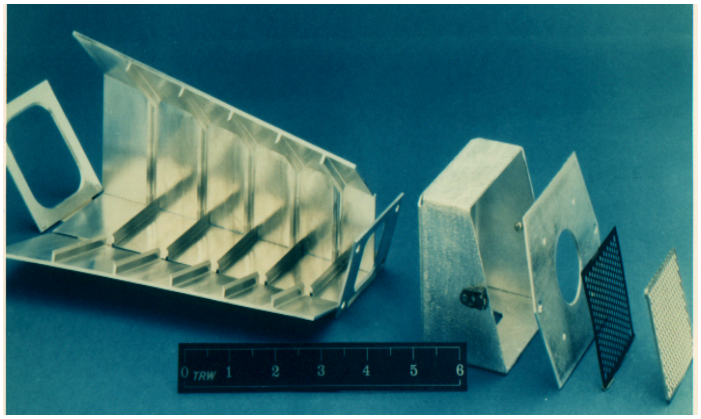
	DCC 3-channel	Unfiltered Radiance	>100 Km	Monthly	Inter-Channel consistency, stability	TOT, SW
	TIme Space Averaging	Fluxes	Global	Monthly	Inter-Instrument Agreement	LW, SW
	Lunar Radiance Measurements	Filtered Radiance	Sub Pixel	Quarterly	Inter-Instrument Agreement	LW, SW, WN

CERES Solar Calibration

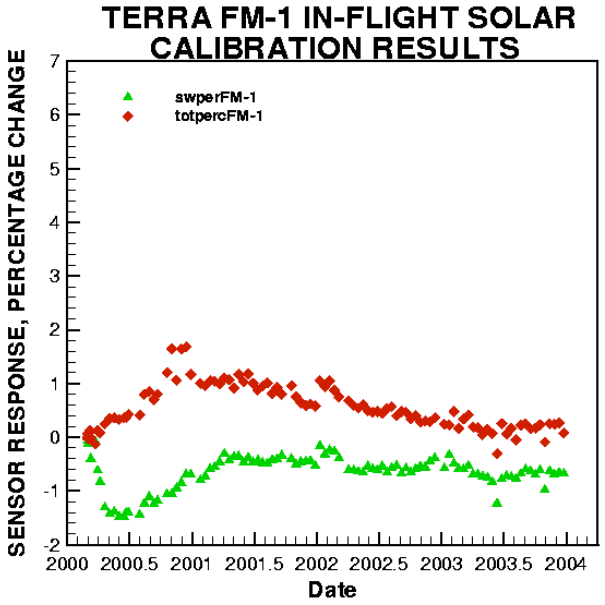
Mirror Attenuator Mosaic (MAM)

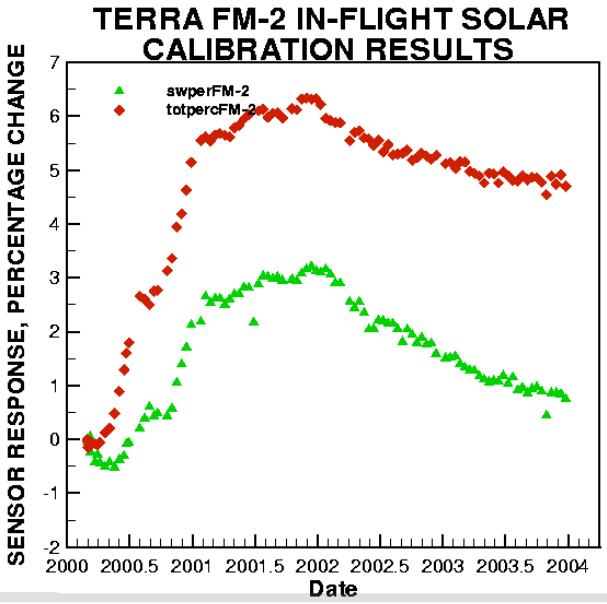
- Solar Diffuser plate attenuates direct solar view
- MAM is a Nickel substrate with Aluminum coated spherical cavities or divots
- Provides a Relative calibration of the Shortwave channel and the SW portion of the Total channel

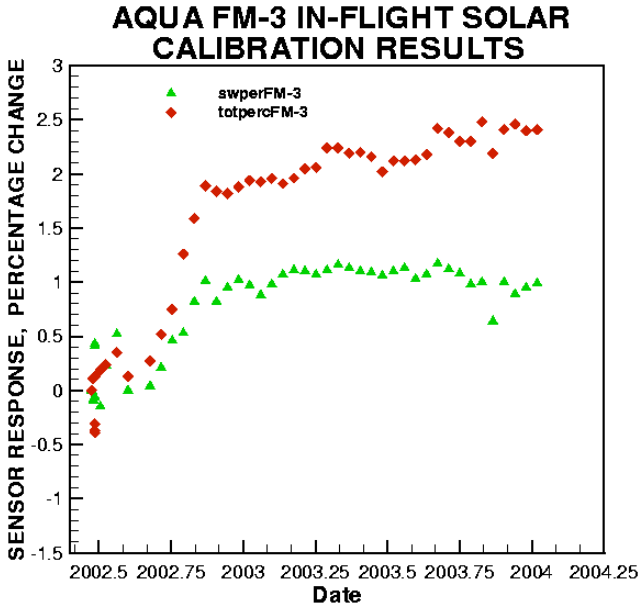


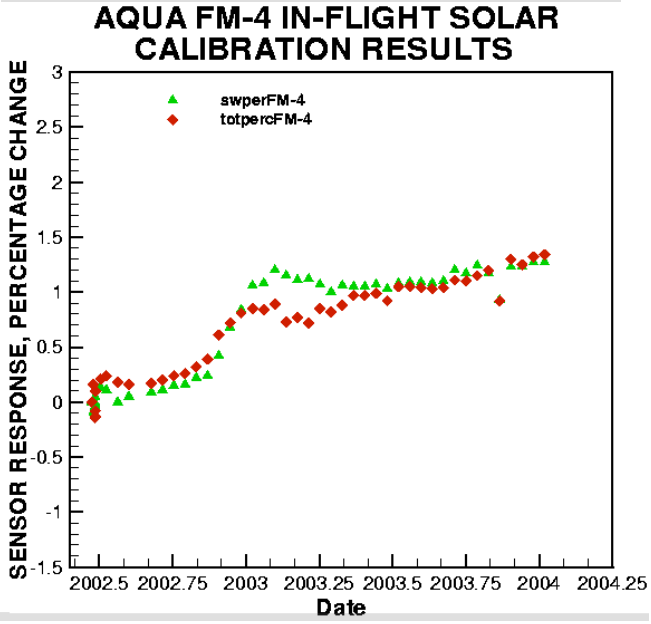


CERES Solar Calibration Results









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	Lunar Radiance Measurements	Filtered Radiance	Sub Pixel	Quarterly	Inter-Instrument Agreement	LW, SW, WN

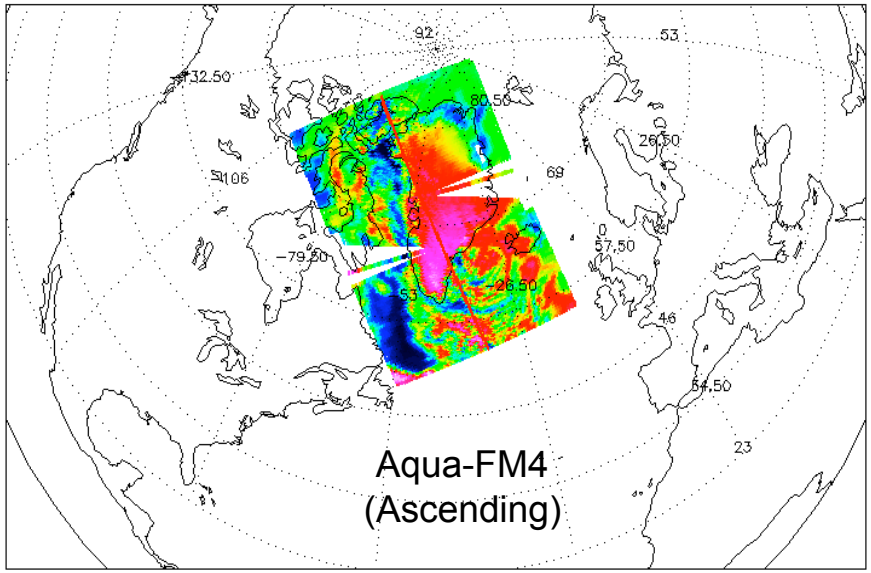
Terra/aqua Inter-Calibration Over Greenland

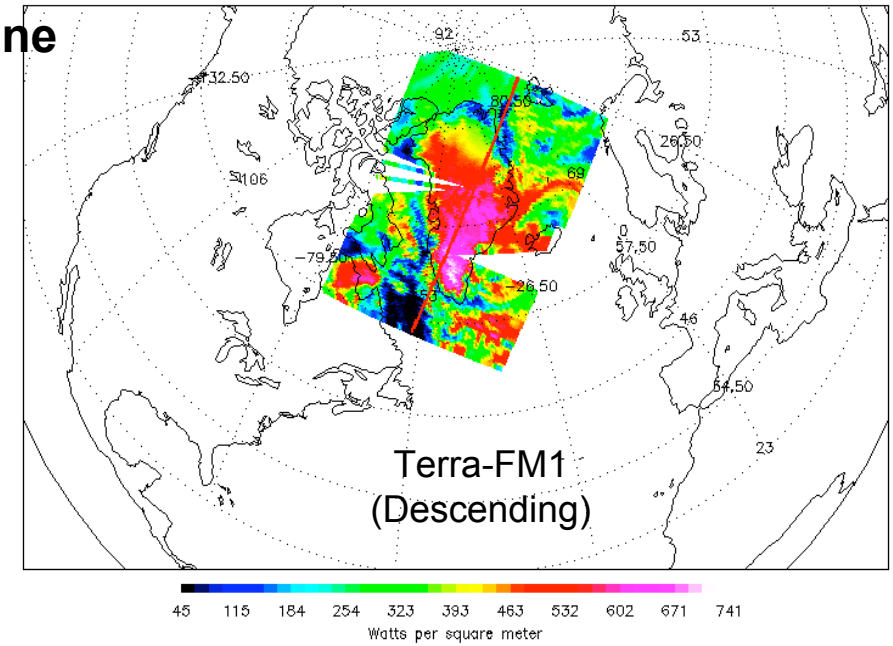
Strategy

- **FM1 and FM4 instruments were utilized**
- **Orbits intersect at 69.5 deg**
- **Temporal matching <15 mins**
- **VZA matched within 10 deg**
- **Scan planes set orthog. to principal plane**
- **Data collected for 5-deg lat. Swath**
- **About 90 sec of data per orbit**

Campaigns

- **07/04-08/22, 2002**
  - **600 orbital crossings**
- **06/13 - 06/29, 2003**
  - **250 orbital crossings**





Terra/Aqua Zonal Inter-Calibration

Direct Comparison of radiances

- **Difference of averages**

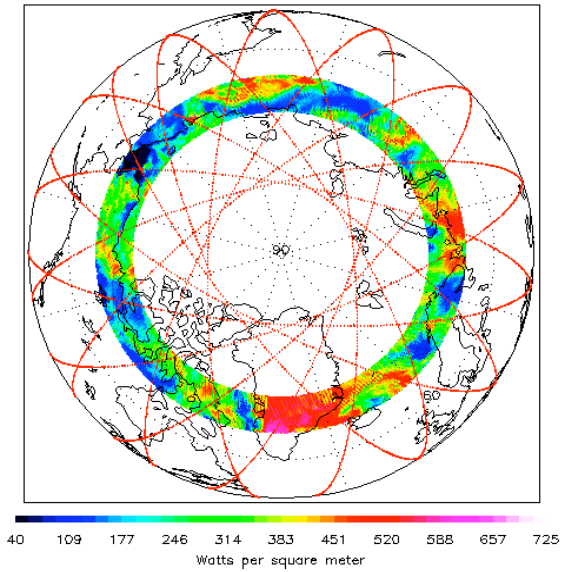
Spatial noise dominates

- **Averaging over 1° x 1° grid-boxes**
- **At least 20 footprints or 75% of area covered**

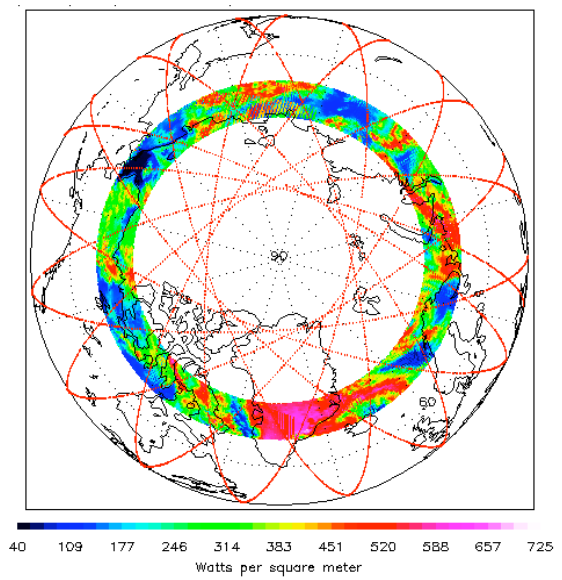
Matching Geometry

- **10° tolerance for viewing zenith angles**
- **20° tolerance for relative azimuth for SW**

Terra-FM1
(Descending)



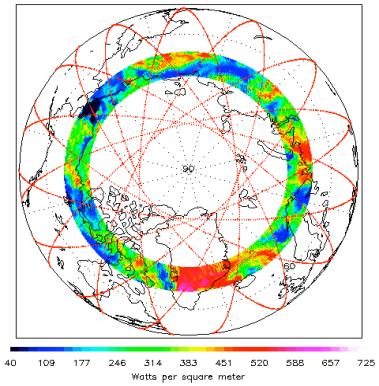
Aqua-FM4
(Ascending)



Terra/Aqua Intercalibration

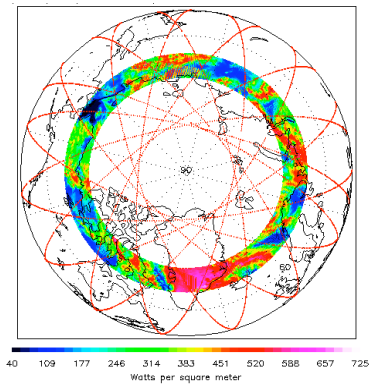
FM1 and FM4 Zonal Comparison

Edition1
2002



Terra-FM1
(Descending)

Aqua-FM4
(Ascending)



	Mean	Abs Diff	% Diff	$\Delta\sigma$	n	α-test
SW	88.6	-0.36	-0.4	0.74	508	0.08
LW_{day}	76.7	0.54	0.7	0.18	508	0.02
LW_{night}	55.1	0.06	0.1	0.10	527	0.01
WN_{day}	5.5	0.05	0.9	0.03	508	0.00
WN_{night}	3.0	0.03	1.0	0.01	527	0.00

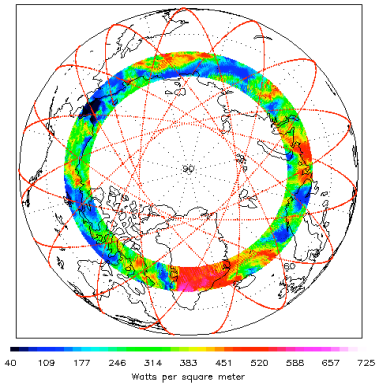
All units in $W/m^2/sr$ **Mean = FM4**
Diff = FM4 - FM1

Data Products: **FM1 - Edition2**
FM4 - Edition1

Terra/Aqua Intercalibration

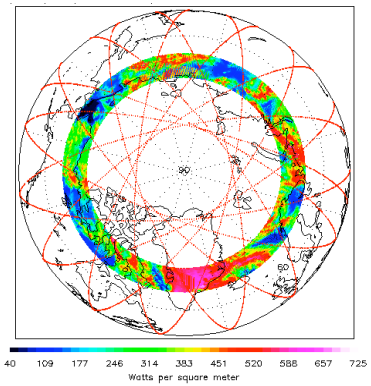
FM1 and FM4 Zonal Comparison

Edition1
2003



Terra-FM1
(Descending)

Aqua-FM4
(Ascending)



	Mean	Abs Diff	% Diff	$\Delta\sigma$	n	α-test
SW	92.5	-0.56	-0.6	0.69	236	0.1
LW_{day}	78.4	1.48	1.9	0.31	236	0.1
LW_{night}	55.8	0.13	0.2	0.10	242	0.00
WN_{day}	5.6	0.04	0.7	0.03	236	0.01
WN_{night}	3.1	0.03	0.9	0.01	242	0.01

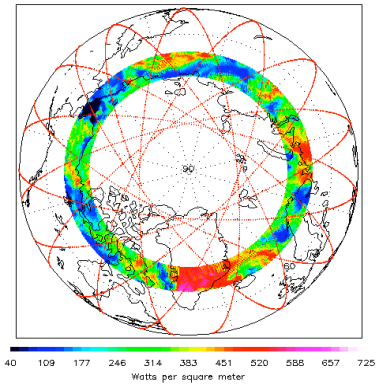
All units in $W/m^2/sr$ **Mean = FM4**
Diff = FM4 - FM1

Data Products: **FM1 - Edition2**
FM4 - Edition1

Terra/Aqua Intercalibration

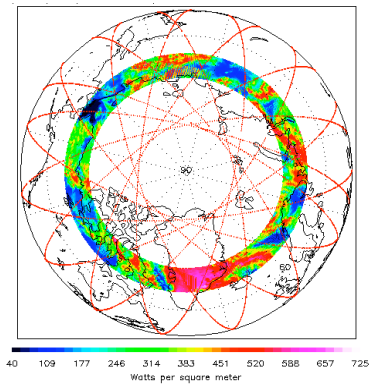
FM1 and FM4 Zonal Comparison

Edition2
2002



Terra-FM1
(Descending)

Aqua-FM4
(Ascending)



	Mean	Abs Diff	% Diff	$\Delta\sigma$	n	α-test
SW	93.0	-0.33	-0.4	0.77	346	0.1
LW_{day}	77.2	0.43	0.6	0.19	346	0.02
LW_{night}	55.1	0.07	0.1	0.10	344	0.01
WN_{day}	5.6	0.05	0.9	0.03	346	0.00
WN_{night}	3.0	0.03	1.0	0.01	344	0.00

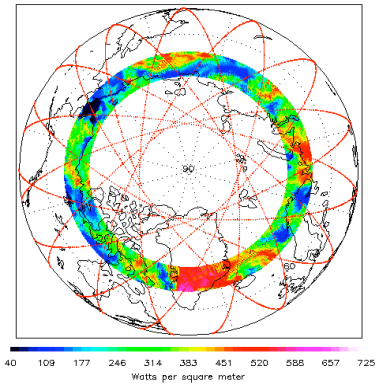
All units in $W/m^2/sr$ **Mean = FM4**
Diff = FM4 - FM1

Data Products: **FM1 - Edition2**
FM4 - Edition2

Terra/Aqua Intercalibration

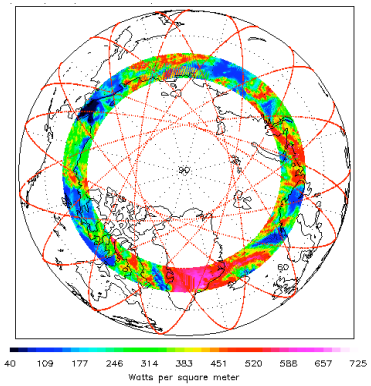
FM1 and FM4 Zonal Comparison

Edition2
2003



Terra-FM1
(Descending)

Aqua-FM4
(Ascending)



	Mean	Abs Diff	% Diff	$\Delta\sigma$	n	α-test
SW	92.3	-0.86	-0.9	0.71	234	0.1
LW_{day}	77.7	0.69	0.9	0.19	234	0.1
LW_{night}	55.7	0.03	0.1	0.10	240	0.00
WN_{day}	5.6	0.04	0.7	0.02	234	0.1
WN_{night}	3.1	0.03	0.9	0.01	240	0.1

All units in $W/m^2/sr$ **Mean = FM4**
Diff = FM4 - FM1

Data Products: **FM1 - Edition2**
FM4 - Edition2

CERES Instrument Radiometric Validation Activities

		Product	Spatial Scale	Temporal Scale	Metric	Spectral Band
On-Board	Internal BB	Filtered Radiance	N/A	N/A	Absolute Stability	TOT, WN
	Internal Lamp	Filtered Radiance	N/A	N/A	Absolute Stability	SW
	Solar	Filtered Radiance	N/A	N/A	Relative Stability	TOT, SW
Vicarious	Theoretical Line-by-Line	Filtered Radiance	> 20 Km	Instantaneous	Inter-Channel Theoretical Agreement	TOT, WN
	Unfiltering Algorithm Theoretical Validation	N/A	N/A	N/A	N/A	TOT, SW, WN
	Inter-satellite (Direct Comparison)	Unfiltered Radiance	1-deg Grid	1 per crossing	Inter-Instrument Agreement, Stability	TOT, SW, WN
	Globally Matched Pixels (Direct Comparison)	Unfiltered Radiance	Pixel to Pixel	Daily	Inter-Instrument Agreement	TOT, SW, WN
	Tropical Mean (Geographical Average)	Unfiltered Radiance	20N – 20S	Monthly	Inter-Channel Agreement, Stability	TOT, WN
	DCC Albedo	Unfiltered Radiance	>40 Km	Monthly	Inter-Instrument agreement, Stability	SW
	DCC 3-channel	Unfiltered Radiance	>100 Km	Monthly	Inter-Channel consistency, stability	TOT, SW
	TIme Space Averaging	Fluxes	Global	Monthly	Inter-Instrument Agreement	LW, SW
	Lunar Radiance Measurements	Filtered Radiance	Sub Pixel	Quarterly	Inter-Instrument Agreement	LW, SW, WN

Direct Comparison of Nadir Radiance Measurements

Two CERES instruments on a common platform allows for a unique validation opportunity…..

Direct Comparison of simultaneous Nadir measurements

Each CERES/Terra instrument views nadir every 3.3 seconds

Thus, we obtain nearly simultaneous measurements of the same geo-location ($\Delta t < 3.3$ seconds)….

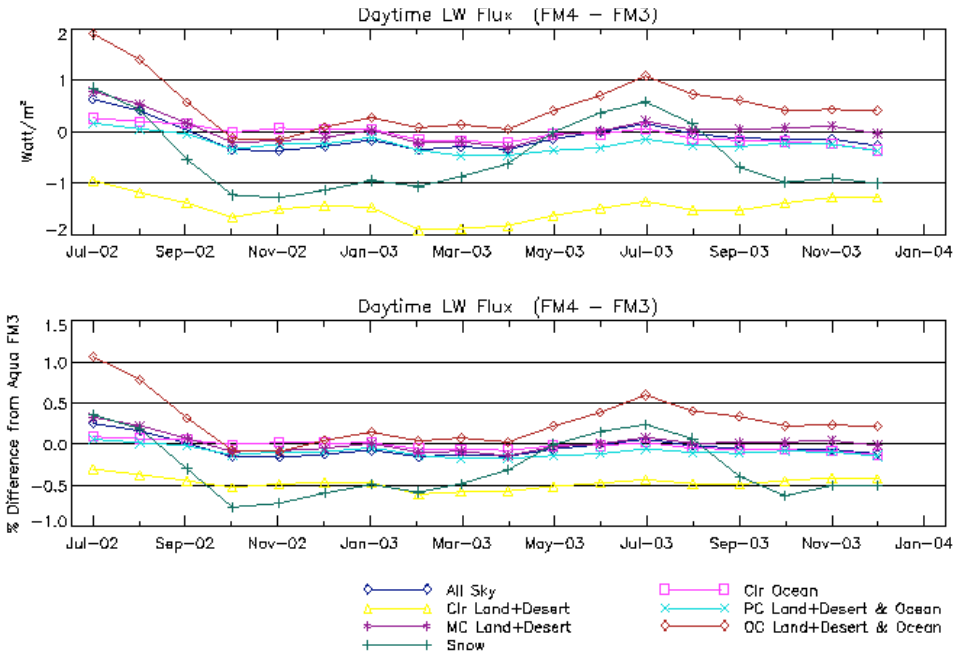
Spatial, angular, and temporal sampling issues are virtually eliminated.

26,000 co-located (but not independent) measurements in a given day, provides a very rigorous statistical tool.

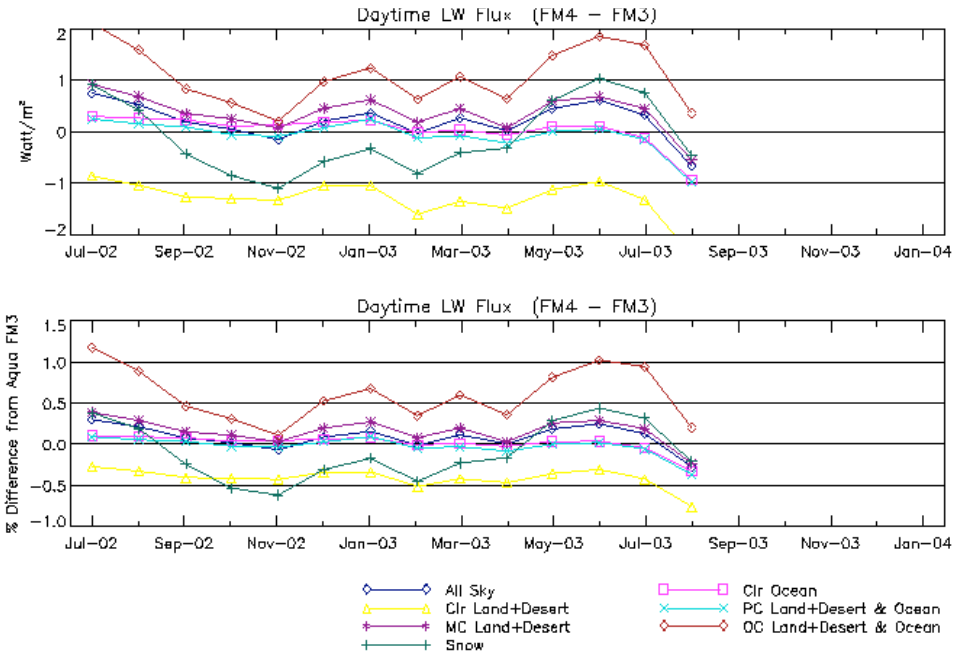
Results can be discretized by scene type to enhance the analysis.

Aqua Daytime LW Flux

Edition 1

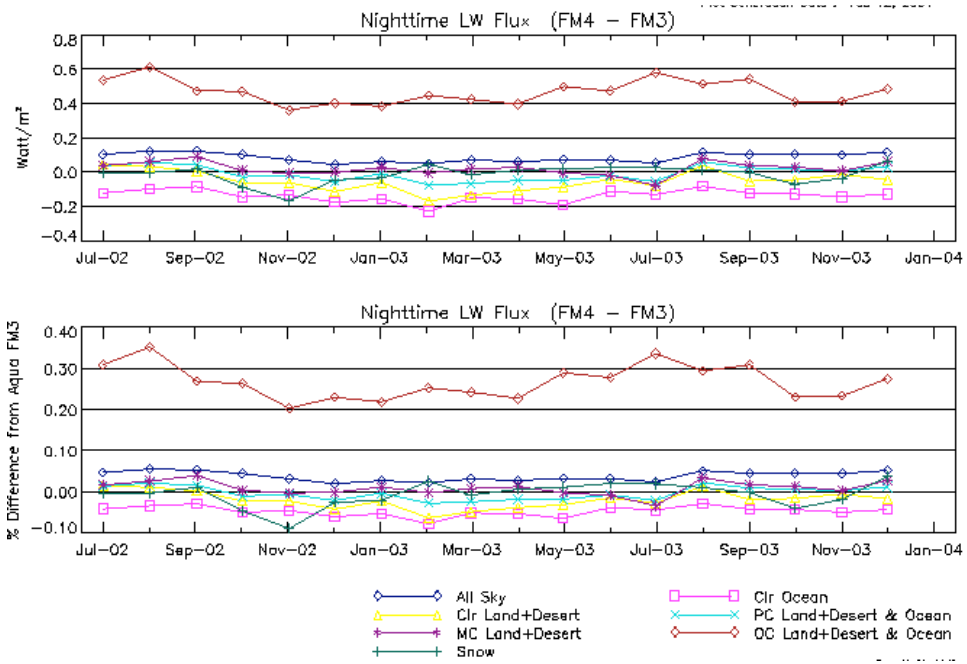


Edition 2

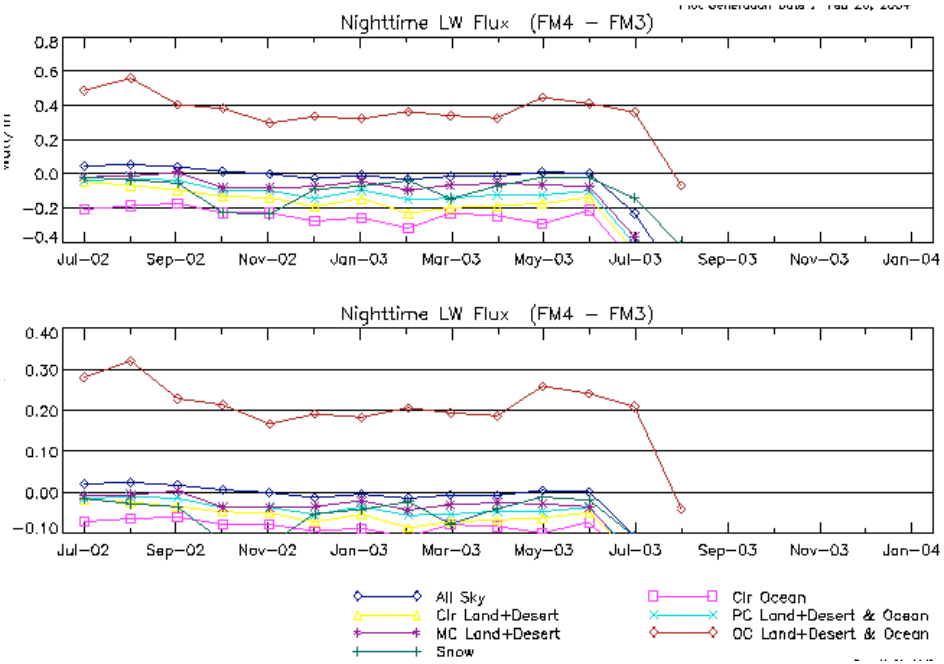


Aqua Nighttime LW Flux

Edition 1

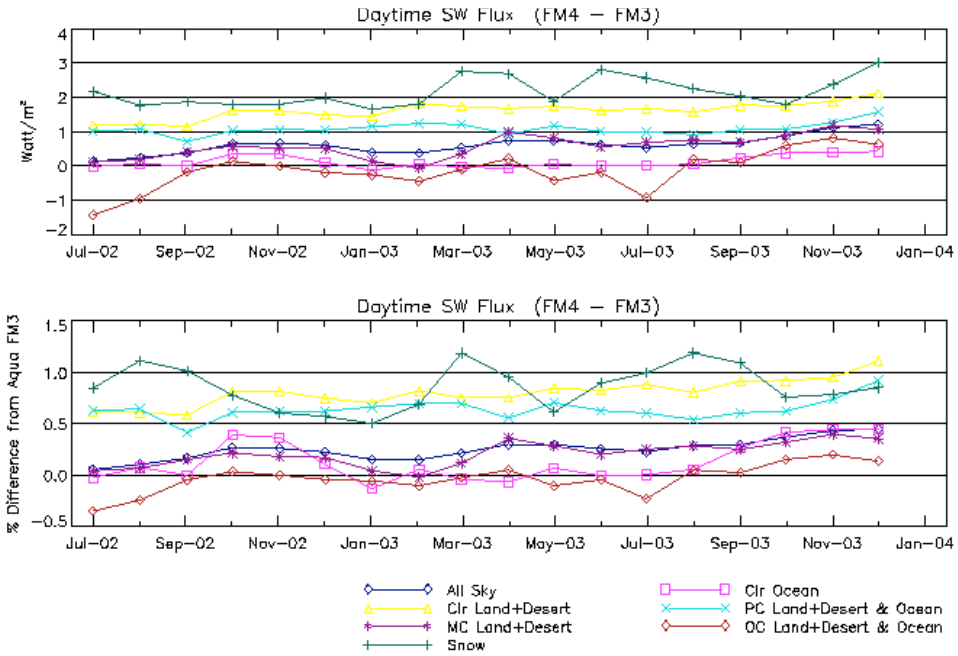


Edition 2

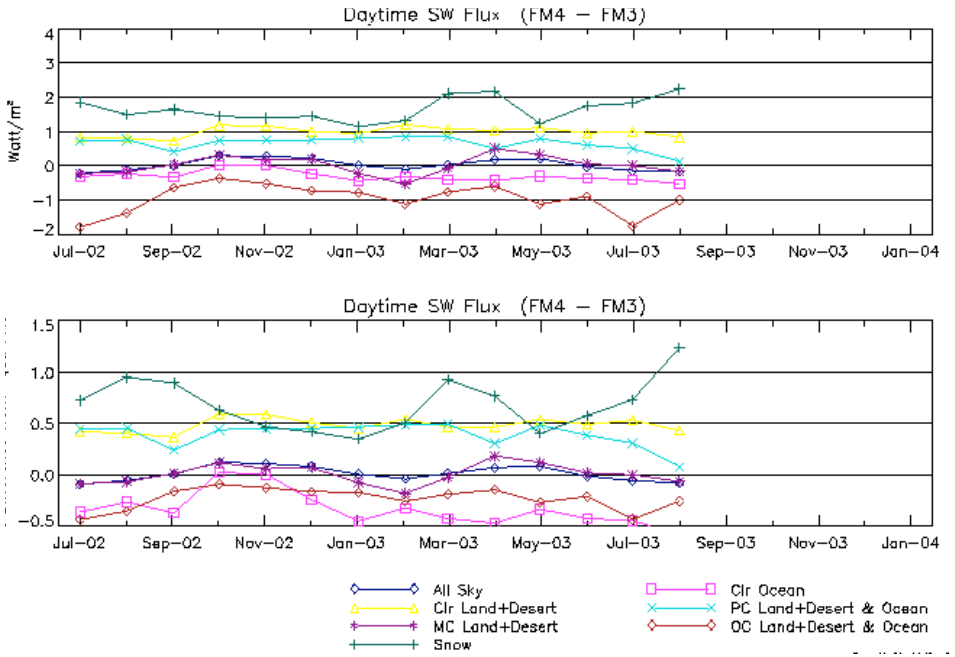


Aqua SW Flux

Edition 1

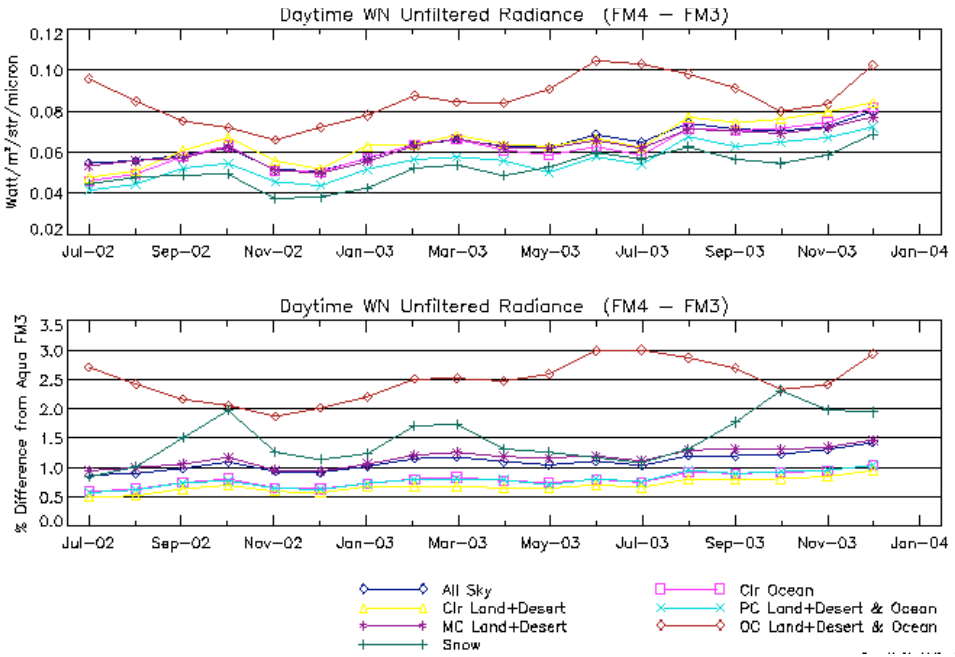


Edition 2

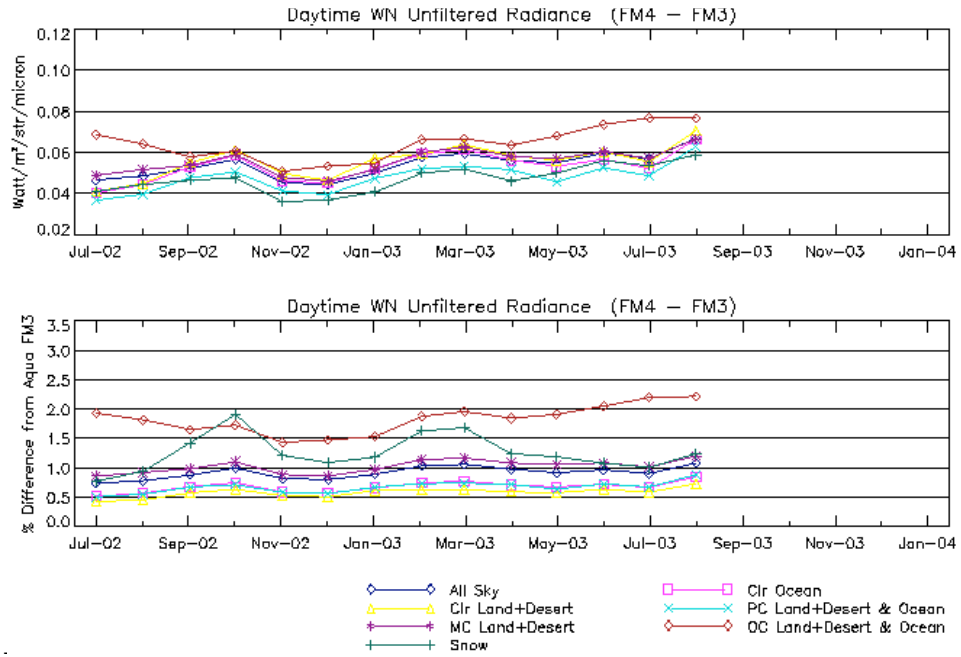


Aqua Daytime WN Flux

Edition 1

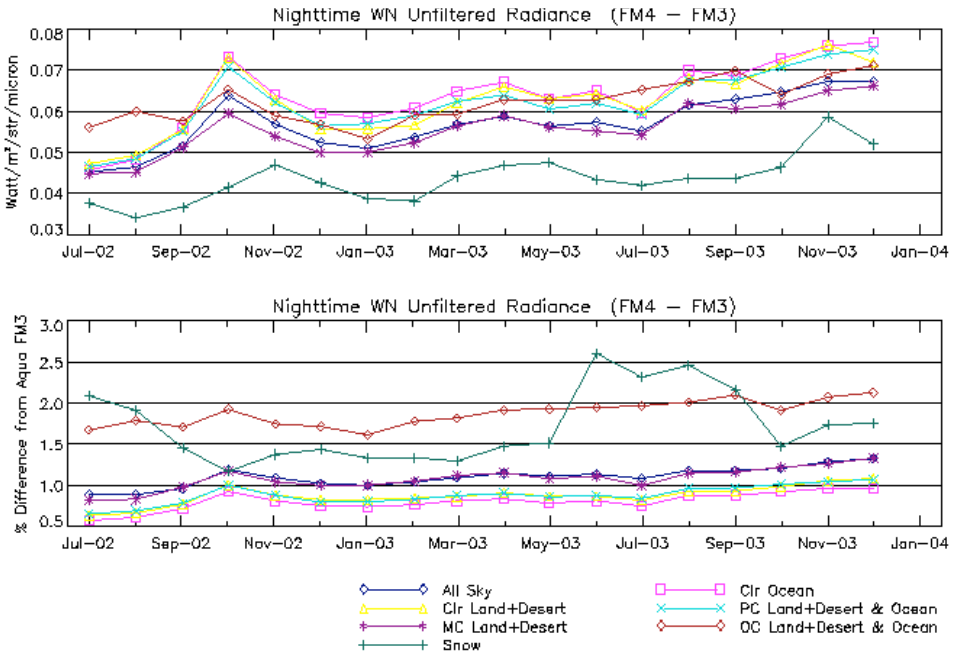


Edition 2

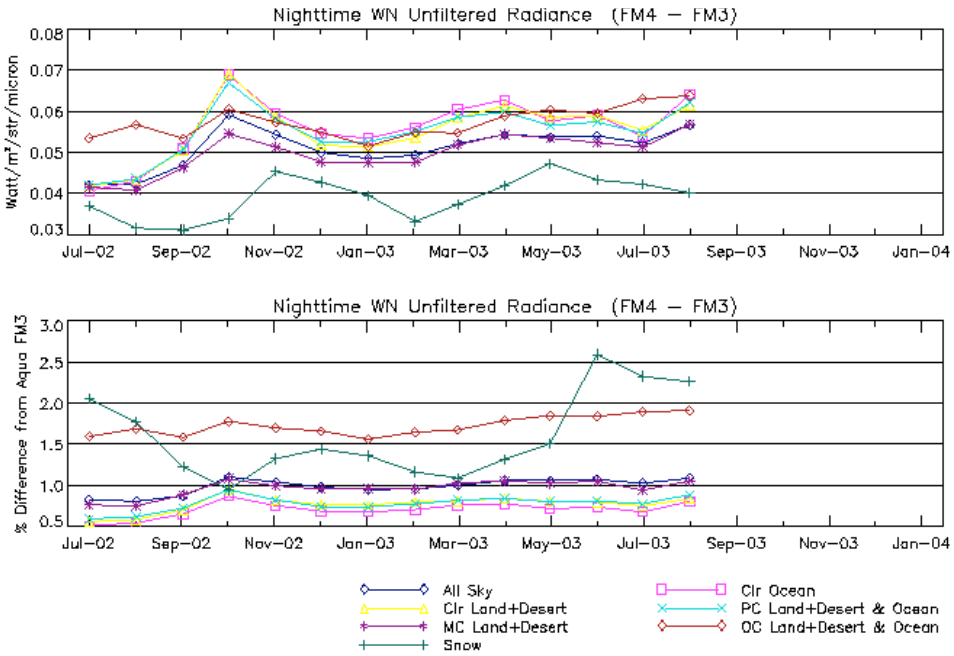


Aqua Nighttime WN Flux

Edition 1



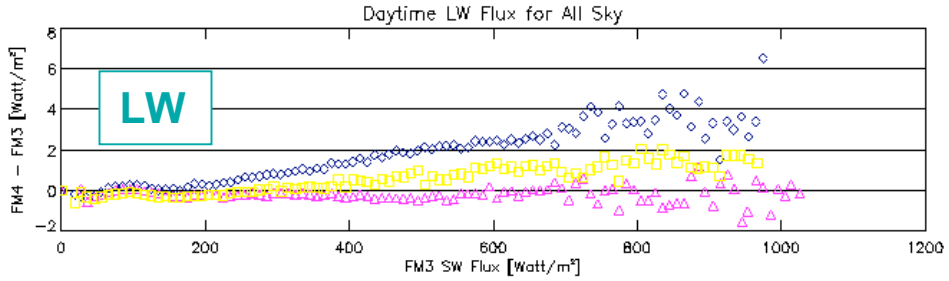
Edition 2

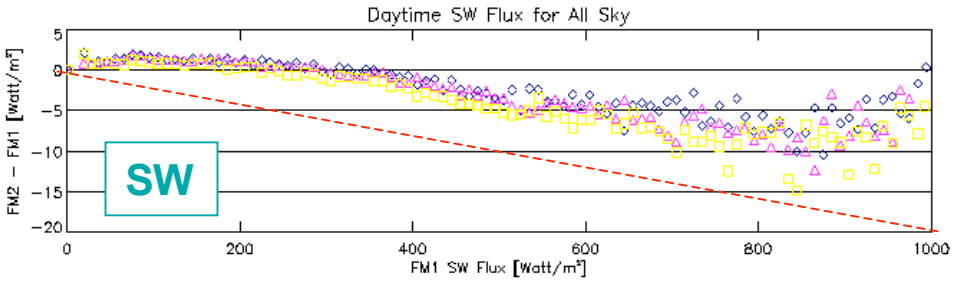


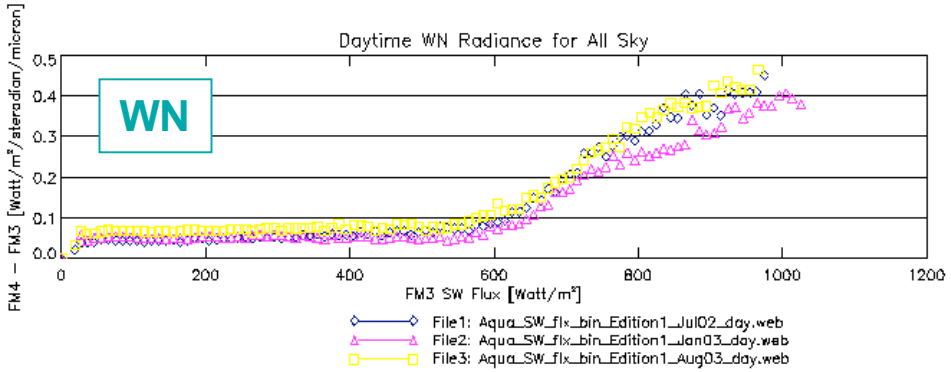
Aqua Binned Flux Comparison

LW, SW, and WN Radiances

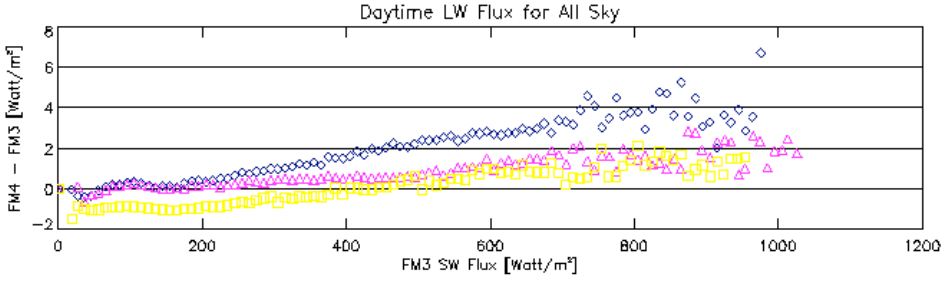
Edition 1

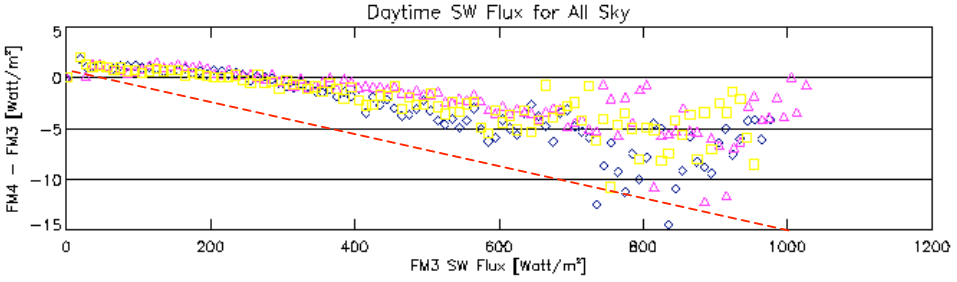


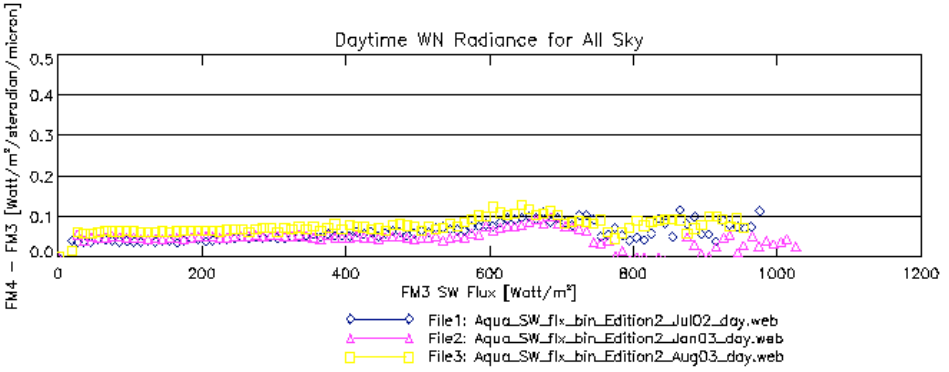




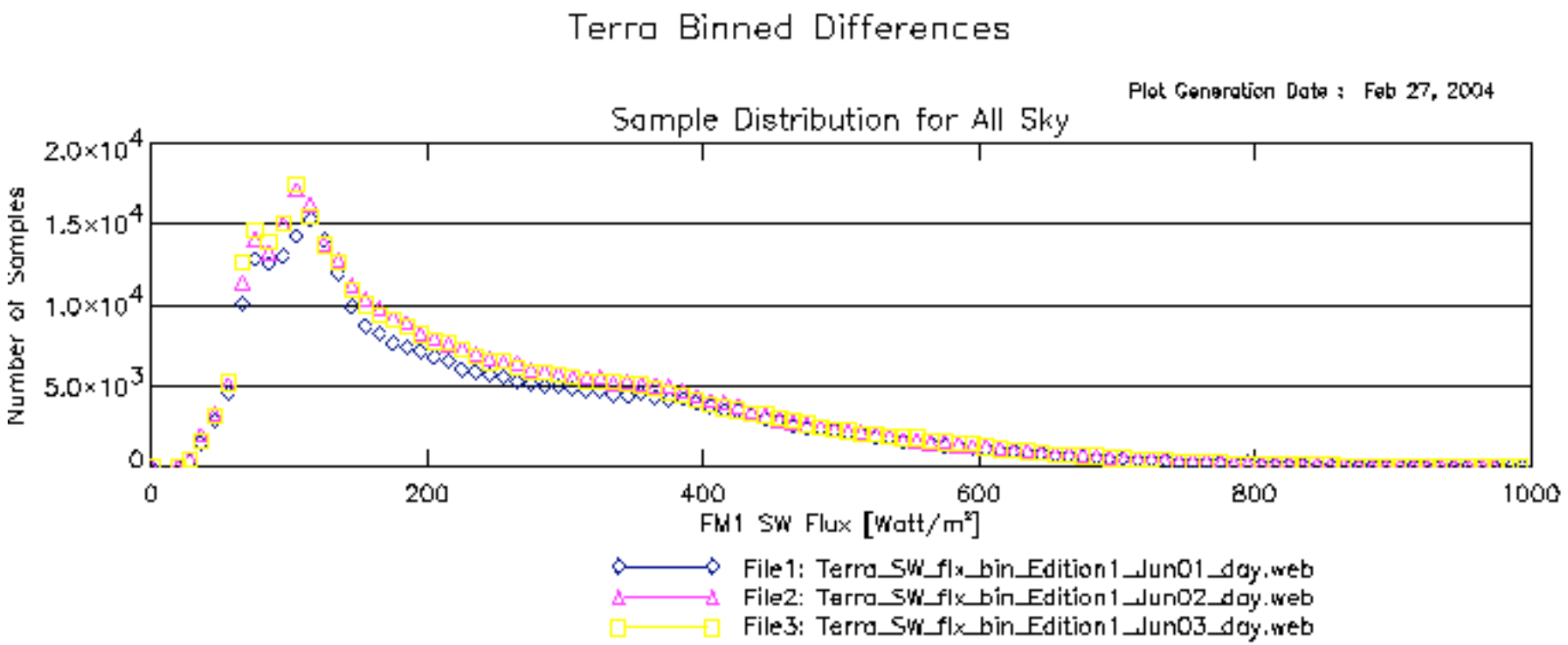
Edition 2







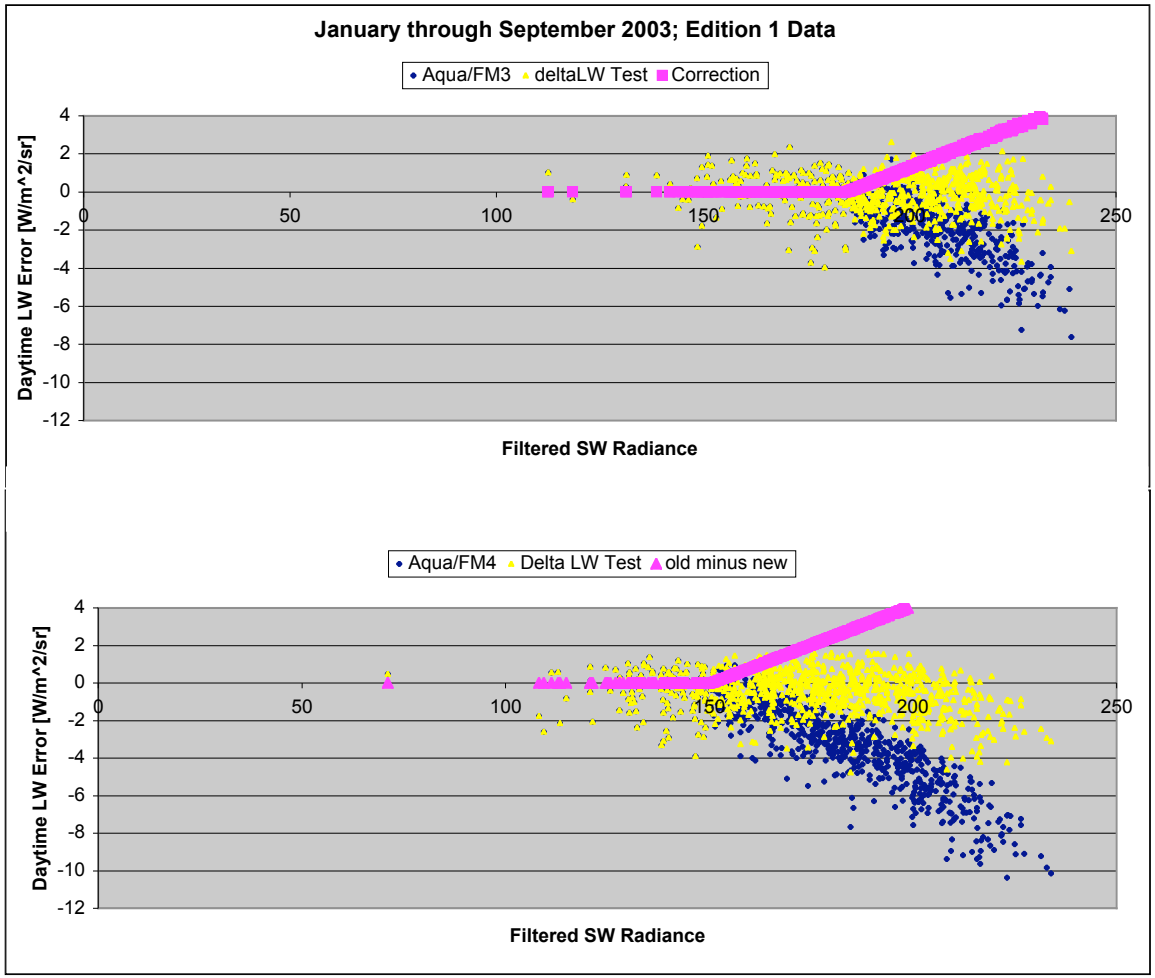
Binned Flux Comparison Footprint Distribution



Aqua Three Channel Inter-Comparison

WN Channel SW sensitivity correction

Edition1 data



CERES Cal/Val Summary

Terra/Aqua

- All radiometric goals have been met or exceeded in Edition2 products
- Edition2 BDS and ERBE-like products available through 6/03
- Rigoruous validation protocol has removed on orbit radiometric transients
- Still some residual correlation with SW (scene brightness)
- WN channel SW sensitivity has been accounted for in…
  - Aqua Edition2 Data Products (All)
  - Terra Edition2 Data Products from 7/03 onward
- Unprecedented stability levels of ~0.1%/yr for CERES climate record